JC02 Rec'd PCT/PTO 25 MAR 2002

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| FORM PTO-1390 (REV. 5-93) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE | ATTORNEY'S DOCKET NUMBER **10191/2304** |
| **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371** | U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 10/089018 |

| INTERNATIONAL APPLICATION NO. | INTERNATIONAL FILING DATE | PRIORITY DATE CLAIMED: |
|---|---|---|
| **PCT/DE00/02931** | **26 August 2000 (26.08.00)** | **24 September 1999 (24.09.99)** |

TITLE OF INVENTION
MICROMECHANICAL YAW RATE SENSOR

APPLICANT(S) FOR DO/EO/US
**Joerg HAUER, Michael FEHRENBACH, and Karsten FUNK**

Applicants herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information.

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U S.C 371.
3. ☒ This is an express request to begin national examination procedures (35 U S C 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date
5. ☒ A copy of the International Application as filed (35 U.S C 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C 371(c)(2))
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U S C 371(c)(3))
   a ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have. been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U S.C. 371(c)(3))
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) (unsigned).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C 371(c)(5))

**Items 11. to 16. below concern other document(s) or information included:**

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1 98
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3 31 is included.
13. ☒ A **FIRST** preliminary amendment.
14. ☒ A substitute specification and marked-up version thereof
15. ☐ A change of power of attorney and/or address letter
16. ☒ Other items or information: International Search Report (translated), Preliminary Examination Report (translated) and PCT/RO/101.

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| U.S. APPLICATION NO. if known, see 37 C.F.R.1.5 10/089018 | INTERNATIONAL APPLICATION NO PCT/DE00/02931 | ATTORNEY'S DOCKET NUMBER 10191/2304 |
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| | CALCULATIONS | PTO USE ONLY |
|---|---|---|
| 17. ☒ The following fees are submitted:<br>**Basic National Fee (37 CFR 1.492(a)(1)-(5)):**<br>Search Report has been prepared by the EUROPEAN PATENT OFFICE or JPO . . . . . $890.00<br>International preliminary examination fee paid to USPTO (37 CFR 1.482) . . . . . . $710.00<br>No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) . . . . . $740.00<br>Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO . . . . . $1,040.00<br>International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) . . . . . $100.00 | | |
| **ENTER APPROPRIATE BASIC FEE AMOUNT =** | $ 890 | |
| Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)). | $ | |

| Claims | Number Filed | Number Extra | Rate | | |
|---|---|---|---|---|---|
| Total Claims | 7 - 20 = | 0 | X $18.00 | $ 0 | |
| Independent Claims | 1 - 3 = | 0 | X $84.00 | $ 0 | |
| Multiple dependent claim(s) (if applicable) | | | + $280.00 | $ | |
| **TOTAL OF ABOVE CALCULATIONS =** | | | | $ 890 | |
| Reduction by ½ for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28). | | | | $ | |
| **SUBTOTAL =** | | | | $ 890 | |
| Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). + | | | | $ | |
| **TOTAL NATIONAL FEE =** | | | | $ 890 | |
| Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property + | | | | $ | |
| **TOTAL FEES ENCLOSED =** | | | | $ 890 | |
| | | | | Amount to be: refunded | $ |
| | | | | charged | $ |

a. ☐ A check in the amount of $__________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of **$890.00** to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

By: W. Magnk (Reg. No. 41,172)

Richard L. Mayer

SIGNATURE

SEND ALL CORRESPONDENCE TO:
Kenyon & Kenyon
One Broadway
New York, New York 10004

**Customer No. 26646**

Richard L. Mayer, Reg. No. 22,490
NAME

3/25/01
DATE

10/089018
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[10191/2304]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | | |
|---|---|---|
| Inventors | : | HAUER et al. |
| Serial No. | : | To Be Assigned |
| Filed | : | Herewith |
| For | : | MICROMECHANICAL YAW RATE SENSOR |
| Examiner | : | To Be Assigned |
| Art Unit | : | To Be Assigned |

Assistant Commissioner
for Patents
Washington, D.C. 20231
Box Patent Application

**PRELIMINARY AMENDMENT AND**
**37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT**

SIR:

Please amend the above-identified application before examination, as set forth below.

**IN THE SPECIFICATION AND ABSTRACT:**

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

**IN THE CLAIMS:**

On the first page of the claims, first line, change "What is claimed is:" to: --What Is Claimed Is:--.

Please cancel original claims 1 to 7, without prejudice, in the underlying PCT Application No. PCT/DE00/02931.

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Please add the following new claims:

8. (New) A micromechanical yaw rate sensor, comprising:

a substrate;

a bridge;

an anchoring device provided on the substrate and including two opposite bases that are connected fixedly with the substrate and that are connected with one another via the bridge;

a flexural spring device; and

an annular flywheel that is connected via the flexural spring device with the anchoring device such that an area of connection with the anchoring device is located essentially in a center of a ring of the flexural spring device, so that the annular flywheel is able to be displaced, elastically from a rest position, about an axis of rotation situated perpendicular to a surface of the substrate, and about at least one axis of rotation situated parallel to the surface of the substrate, wherein:

at least one V-shaped flexural spring of the flexural spring device is attached to each of opposite sides of the bridge in such a way that an apex is situated on the bridge and limbs of the bridge are spread towards the annular flywheel with an opening angle.

9. (New) The micromechanical yaw rate sensor according to claim 8, wherein:

the at least one V-shaped flexural spring includes a first V-shaped flexural spring and a second V-shaped flexural spring, and

the opening angle is equal for the first V-shaped flexural spring and the second V-shaped flexural spring.

10. (New) The micromechanical yaw rate sensor according to claim 9, wherein:

the first V-shaped flexural spring and the second V-shaped flexural spring are attached to the bridge such that the first V-shaped flexural spring and the second V-shaped flexural spring form an X shape.

11. (New) The micromechanical yaw rate sensor according to claim 10, wherein:
the opening angle is selected such that a natural frequency about the axis of rotation situated perpendicular to the surface of the substrate is smaller than each natural frequency about the axis of rotation situated parallel to the surface of the substrate.

12. (New) The micromechanical yaw rate sensor according to claim 8, wherein:
the two opposite bases are in the shape of a wedge and include two wedge tips, and
the bridge connects the two wedge tips with one another.

13. (New) The micromechanical yaw rate sensor according to claim 8, wherein:
the bridge is suspended freely over the substrate from the two opposite bases.

14. (New) The micromechanical yaw rate sensor according to claim 8, wherein:
the micromechanical yaw rate sensor can be manufactured using one of silicon surface micromechanical technology and another micromechanical technology.

**Remarks**

This Preliminary Amendment cancels original claims 1-7, without prejudice, in the underlying PCT Application No. PCT/DE00/02931. The Preliminary Amendment also adds new claims 8-14. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE00/02931 includes an International Search Report, dated February 12, 2001, and an International Preliminary Examination Report, dated May 30, 2001, copies of which are submitted herewith.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

KENYON & KENYON

By: [signature] (Reg. No. 41,172)

Dated: 3/25/02

By: Richard L. Mayer

Richard L. Mayer
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[10191/2304]

# MICROMECHANICAL YAW RATE SENSOR

## Field Of The Invention

The present invention relates to a micromechanical yaw rate sensor, having a substrate that has an anchoring device provided on the substrate, and having an annular flywheel that is connected, via a flexural spring device, with the anchoring device in such a way that the area of connection with the anchoring device is located essentially in the center of the ring, so that the annular flywheel is able to be displaced, elastically from its rest position, about an axis of rotation situated perpendicular to the substrate surface, and about at least one axis of rotation situated parallel to the substrate surface.

## Background Information

Yaw rate sensors are known from M. Lutz, W. Golderer, J. Gerstenmeier, J. Marek, B. Maihöfer, and D. Schubert, "A Precision Yaw Rate Sensor in Silicon Micromachining"; SAE Technical Paper, 980267, and from K. Funk, A. Schilp, M. Offenberg, B. Elsner, and F. Lärmer, "Surface-micromachining of Resonant Silicon Structures"; The 8th International Conference on Solid-State Sensors and Actuators, Eurosensors IX, Stockholm, Sweden, 25-29 June 1995, pp. 50-52.

Figure 2 shows a schematic top view of a known micromechanical yaw rate sensor.

In Figure 2, the character 100 designates a substrate in the form of a silicon wafer. 10 designates an annular flywheel; 15, 15' designate flexural sensors; 25 designates a bridge; 18, 18' designate a respectively curved flexural spring, and 20, 20' designate a base. The latter parts are manufactured from polysilicon over a silicon oxide layer, the silicon oxide layer being removed later in the process through undermining, in order to form the parts so that they can be displaced in relation to substrate 100. Only the two bases 20, 20' are anchored on the substrate over the silicon oxide layer, and form fixed points of the sensor structure.

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SUBSTITUTE SPECIFICATION

The functioning of the yaw rate sensor constructed in this manner is based on the principle of the law of conservation of angular momentum of a rotating system.

In general, the following holds:

$$\overline{M} = \overline{J \cdot \tfrac{d\omega}{dt}} \; x \; \overline{\Omega} \, ,$$

where M is the moment of deviation, J is the mass moment of inertia, dω/dt is the angular velocity of the rotary oscillation, and Ω is the sought yaw rate.

If, in the known yaw rate sensor according to Figure 2, annular flywheel 10, which is rotating about the z axis, is rotated about its y axis, this flywheel performs a rotation about the x axis. Given a constant angular velocity about the z axis, this rotation about the x axis, which is caused by the above moment of deviation M, is directly proportional to the sought yaw rate Ω.

In general, the problematic on which the present invention is based is that the first three natural frequencies corresponding to the x, y, and z axes, indicated in the Figure, do not have a position that is optimal or that can be optimized easily in the context of a process.

In particular, a modification of the sensor mass for the adjustment of the first three natural frequencies is undesirable, because this has effects that are disturbing with respect to measurement technology.

<u>Summary Of The Invention</u>

The underlying idea of the present invention is that the anchoring device has two bases, situated opposite one another, that are connected fixedly with the substrate and are connected with one another via a bridge. A V-shaped flexural spring of the flexural spring device is attached to each of the opposed sides of the bridge in such a way that the apex is located on the bridge, and the limbs are spread out towards the flywheel with an opening angle.

The first natural frequency about the z axis can be set by determining the spring width and spring length of the V-shaped flexural springs, corresponding to the operating frequency in the forced mode of the sensor. By modifying the opening angle between the respective spring limbs, the detection resonance frequency of the sensor, i.e., the rotation out of the plane of the substrate about the x or y axis, can be set. The ratio of the natural frequencies to one another determines, to a considerable extent, the sensor properties, such as for example sensitivity, immunity to interference, and temperature stability.

The inventive micromechanical yaw rate sensor therefore has, in relation to the known solutions, the particular advantage that via the opening angle, or the width and length, of the V-shaped flexural springs, the natural frequencies can be adjusted in a simple and precise manner, independently of one another.

According to a preferred development, the opening angle is equal for both V-shaped flexural springs of the flexural spring device. Thus, only one angle need be optimized for the natural frequencies.

According to a further preferred development, the V-shaped flexural springs of the flexural spring device are attached to the bridge in such a way that they form an X shape. This creates a symmetrical shape of the flexural springs.

According to a further preferred development, the opening angle is selected such that the natural frequency about the axis of rotation situated perpendicular to the surface of the substrate is smaller than each natural frequency about an axis of rotation situated parallel to the surface of the substrate. In this way, an extraordinarily positive acquisition characteristic can be achieved.

According to a further preferred development, the bases at the opposed sides are fashioned with a wedge shape. Here, the bridge connects the two wedge tips with one another. In this way, the sensor obtains a good capacity for displacement about the z axis.

According to a further preferred development, the bridge is suspended freely over the substrate.

According to a further preferred development, it can be manufactured using silicon surface micromechanical technology. The use of surface micromechanical technology to manufacture the inventive micromechanical yaw rate sensor, specifically the series production process having a thick epipoly layer, typically 10 μm thick, enables the formation of a rigid sensor structure, which enables a low cross-sensitivity to be achieved.

Brief Description Of The Drawings

Figure 1 shows a schematic top view of a specific embodiment of the inventive micromechanical yaw rate sensor.

Figure 2 shows a schematic top view of a known micromechanical yaw rate sensor.

Detailed Description

In the Figures, identical reference characters designate identical or functionally identical components.

Figure 1 shows a schematic top view of a specific embodiment of the inventive micromechanical yaw rate sensor.

In Figure 1, in addition to the reference characters already introduced, 30-33 designate flexural spring limbs of two V-shaped flexural springs, 25' designates a bridge, 21, 21' designate bases, and 150 designates an electrical supply line.

In the micromechanical yaw rate sensor according to this specific embodiment, as in the known example according to Figure 2, annular flywheel 10 is connected with anchoring device 21, 21', 25 via a flexural spring device made up of the two V-shaped flexural springs, in such a way that anchoring device 20 is located essentially in the center of the ring, so that annular flywheel 10 so that the annular flywheel is able to be displaced, elastically from its rest position, about the z axis, situated perpendicular to the surface of the substrate, and about the x and y axes, situated parallel to the surface of the substrate.

However, anchoring device 21, 21', 25' has two bases 21, 21' situated opposite one another and connected fixedly with substrate 100, and fashioned with a wedge shape at the opposed

sides, bridge 25' connecting the two wedge tips with one another. Bridge 25' is suspended freely over substrate 100 from bases 21, 21'.

At each of the opposite sides of bridge 25', one of the V-shaped flexural springs, made up of limbs 30, 31 or 32, 33, is attached in such a way that the respective apex is located on bridge 25', and limbs 30, 31 or 32, 33 are spread out towards flywheel 10 with an opening angle.

The opening angle is equal for the two V-shaped flexural springs of the flexural spring device, and the V-shaped flexural springs of the flexural spring device are attached to bridge 25' in such a way that they form a symmetrical X shape.

The first natural frequency about the z axis can be set by determining the spring width and spring length of limbs 30, 31, 32, 33 of the V-shaped flexural springs. By determining the opening angle between the respective spring limbs, the natural frequency can be set for the rotation out of the substrate plane about the x or y axis. The ratio of the natural frequencies to one another is determined such that the sensor properties, such as for example sensitivity, immunity to interference, and temperature stability, assume an optimized value specific to the application.

Here the opening angle is for example selected such that the natural frequency about the z axis, situated perpendicular to the substrate surface, is smaller than each natural frequency about an axis of rotation situated parallel to the substrate surface, i.e., the x or y axis.

The micromechanical yaw rate sensor according to this specific embodiment is preferably manufactured using silicon surface micromechanical technology.

Although the present invention has been specified above on the basis of preferred exemplary embodiments, it is not limited to these, but rather can be modified in a multiplicity of ways.

In particular, the geometry of the flywheel, as well as of the flexural spring systems, is not limited to the indicated examples. However, larger deviations from the symmetrical arrangement about the anchoring should be avoided whenever there is a danger that linear portions of the external acceleration will falsify the measurement result.

The described packaging and manufacturing process is likewise to be understood only as an example, and other methods, such as for example galvanic methods, can likewise be used to manufacture the yaw rate sensor.

Abstract Of The Disclosure

A micromechanical yaw rate sensor having: a substrate having an anchoring device provided on the substrate; and an annular flywheel that is connected, via a flexural spring system, with the anchoring device in such a way that the area of connection with the anchoring device is located essentially in the center of the ring, so that the annular flywheel is able to be displaced, elastically from its rest position, about an axis of rotation situated perpendicular to the substrate surface, and about at least one axis of rotation situated parallel to the substrate surface. The anchoring device has two bases that are situated opposite one another and are connected fixedly with the substrate, connected with one another via a bridge. A V-shaped flexural spring of the flexural spring system is attached to each of the opposite sides of the bridge in such a way that the apex is situated on the bridge and the limbs are spread towards the flywheel with an opening angle.

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[10191/2304]

# MICROMECHANICAL YAW RATE SENSOR

[Background Information] Field Of The Invention

The present invention relates to a micromechanical yaw rate sensor, having a substrate that has an anchoring device provided on the substrate, and having an annular flywheel that is connected, via a flexural spring device, with the anchoring device in such a way that the area of connection with the anchoring device is located essentially in the center of the ring, so that the annular flywheel is able to be displaced, elastically from its rest position, about an axis of rotation situated perpendicular to the substrate surface, and about at least one axis of rotation situated parallel to the substrate surface.

Background Information

Yaw rate sensors are known from M. Lutz, W. Golderer, J. Gerstenmeier, J. Marek, B. Maihöfer, and D. Schubert, "A Precision Yaw Rate Sensor in Silicon Micromachining"; SAE Technical Paper, 980267, and from K. Funk, A. Schilp, M. Offenberg, B. Elsner, and F. Lärmer, "Surface-micromachining of Resonant Silicon Structures"; The 8th International Conference on Solid-State Sensors and Actuators, Eurosensors IX, Stockholm, Sweden, 25-29 June 1995, pp. 50-52.

Figure 2 shows a schematic top view of a known micromechanical yaw rate sensor.

In Figure 2, the character 100 designates a substrate in the form of a silicon wafer. 10 designates an annular flywheel; 15, 15' designate flexural sensors; 25 designates a bridge; 18, 18' designate a respectively curved flexural spring, and 20, 20' designate a base. The latter parts are manufactured from polysilicon over a silicon oxide layer, the silicon oxide layer being removed later in the process through undermining, in order to form the parts so that they can be displaced in relation to substrate 100. Only the two bases 20, 20' are anchored on the substrate over the silicon oxide layer, and form fixed points of the sensor structure.

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The functioning of the yaw rate sensor constructed in this manner is based on the principle of the law of conservation of angular momentum of a rotating system.

In general, the following holds:

$$\overline{M} = \overline{J \cdot \tfrac{d\omega}{dt}} \, x \, \overline{\Omega} \,,$$

where M is the moment of deviation, J is the mass moment of inertia, dω/dt is the angular velocity of the rotary oscillation, and Ω is the sought yaw rate.

If, in the known yaw rate sensor according to Figure 2, annular flywheel 10, which is rotating about the z axis, is rotated about its y axis, this flywheel performs a rotation about the x axis. Given a constant angular velocity about the z axis, this rotation about the x axis, which is caused by the above moment of deviation M, is directly proportional to the sought yaw rate Ω.

In general, the problematic on which the present invention is based is that the first three natural frequencies corresponding to the x, y, and z axes, indicated in the Figure, do not have a position that is optimal or that can be optimized easily in the context of a process.

In particular, a modification of the sensor mass for the adjustment of the first three natural frequencies is undesirable, because this has effects that are disturbing with respect to measurement technology.

[Advantages of the] Summary Of The Invention

The underlying idea of the present invention is that the anchoring device has two bases, situated opposite one another, that are connected fixedly with the substrate and are connected with one another via a bridge. A V-shaped flexural spring of the flexural spring device is attached to each of the opposed sides of the bridge in such a way that the apex is located on the bridge, and the limbs are spread out towards the flywheel with an opening angle.

The first natural frequency about the z axis can be set by determining the spring width and spring length of the V-shaped flexural springs, corresponding to the operating frequency in the forced mode of the sensor. By modifying the opening angle between the respective spring limbs, the detection resonance frequency of the sensor, i.e., the rotation out of the plane of the substrate about the x or y axis, can be set. The ratio of the natural frequencies to one another determines, to a considerable extent, the sensor properties, such as for example sensitivity, immunity to interference, and temperature stability.

The inventive micromechanical yaw rate sensor [having the features of claim 1] therefore has, in relation to the known solutions, the particular advantage that via the opening angle, or the width and length, of the V-shaped flexural springs, the natural frequencies can be adjusted in a simple and precise manner, independently of one another.

[Advantageous developments and improvements of the micromechanical yaw rate sensor indicated in claim 1 can be found in the subclaims.]

According to a preferred development, the opening angle is equal for both V-shaped flexural springs of the flexural spring device. Thus, only one angle need be optimized for the natural frequencies.

According to a further preferred development, the V-shaped flexural springs of the flexural spring device are attached to the bridge in such a way that they form an X shape. This creates a symmetrical shape of the flexural springs.

According to a further preferred development, the opening angle is selected such that the natural frequency about the axis of rotation situated perpendicular to the surface of the substrate is smaller than each natural frequency about an axis of rotation situated parallel to the surface of the substrate. In this way, an extraordinarily positive acquisition characteristic can be achieved.

According to a further preferred development, the bases at the opposed sides are fashioned with a wedge shape. Here, the bridge connects the two wedge tips with one another. In this way, the sensor obtains a good capacity for displacement about the z axis.

According to a further preferred development, the bridge is suspended freely over the substrate.

According to a further preferred development, it can be manufactured using silicon surface micromechanical technology. The use of surface micromechanical technology to manufacture the inventive micromechanical yaw rate sensor, specifically the series production process having a thick epipoly layer, typically 10 µm thick, enables the formation of a rigid sensor structure, which enables a low cross-sensitivity to be achieved.

Brief Description Of The Drawings

[An exemplary embodiment of the invention is shown in the drawings, and is explained in more detail in the following specification.]

Figure 1 shows a schematic top view of a specific embodiment of the inventive micromechanical yaw rate sensor[, and].

Figure 2 shows a schematic top view of a known micromechanical yaw rate sensor.

Detailed Description [of the Exemplary Embodiments]

In the Figures, identical reference characters designate identical or functionally identical components.

Figure 1 shows a schematic top view of a specific embodiment of the inventive micromechanical yaw rate sensor.

In Figure 1, in addition to the reference characters already introduced, 30-33 designate flexural spring limbs of two V-shaped flexural springs, 25' designates a bridge, 21, 21' designate bases, and 150 designates an electrical supply line.

In the micromechanical yaw rate sensor according to this specific embodiment, as in the known example according to Figure 2, annular flywheel 10 is connected with anchoring device 21, 21', 25 via a flexural spring device made up of the two V-shaped flexural springs, in such a way that anchoring device 20 is located essentially in the center of the ring, so that annular flywheel 10 so that the annular flywheel is able to be displaced, elastically from its

rest position, about the z axis, situated perpendicular to the surface of the substrate, and about the x and y axes, situated parallel to the surface of the substrate.

However, anchoring device 21, 21', 25' has two bases 21, 21' situated opposite one another and connected fixedly with substrate 100, and fashioned with a wedge shape at the opposed sides, bridge 25' connecting the two wedge tips with one another. Bridge 25' is suspended freely over substrate 100 from bases 21, 21'.

At each of the opposite sides of bridge 25', one of the V-shaped flexural springs, made up of limbs 30, 31 or 32, 33, is attached in such a way that the respective apex is located on bridge 25', and limbs 30, 31 or 32, 33 are spread out towards flywheel 10 with an opening angle.

The opening angle is equal for the two V-shaped flexural springs of the flexural spring device, and the V-shaped flexural springs of the flexural spring device are attached to bridge 25' in such a way that they form a symmetrical X shape.

The first natural frequency about the z axis can be set by determining the spring width and spring length of limbs 30, 31, 32, 33 of the V-shaped flexural springs. By determining the opening angle between the respective spring limbs, the natural frequency can be set for the rotation out of the substrate plane about the x or y axis. The ratio of the natural frequencies to one another is determined such that the sensor properties, such as for example sensitivity, immunity to interference, and temperature stability, assume an optimized value specific to the application.

Here the opening angle is for example selected such that the natural frequency about the z axis, situated perpendicular to the substrate surface, is smaller than each natural frequency about an axis of rotation situated parallel to the substrate surface, i.e., the x or y axis.

The micromechanical yaw rate sensor according to this specific embodiment is preferably manufactured using silicon surface micromechanical technology.

Although the present invention has been specified above on the basis of preferred exemplary embodiments, it is not limited to these, but rather can be modified in a multiplicity of ways.

In particular, the geometry of the flywheel, as well as of the flexural spring systems, is not limited to the indicated examples. However, larger deviations from the symmetrical arrangement about the anchoring should be avoided whenever there is a danger that linear portions of the external acceleration will falsify the measurement result.

The described packaging and manufacturing process is likewise to be understood only as an example, and other methods, such as for example galvanic methods, can likewise be used to manufacture the yaw rate sensor.

## Abstract Of The Disclosure

The invention provides a micromechanical yaw rate sensor having: a substrate [(100)] having an anchoring device [(21; 21')] provided on the substrate; and an annular flywheel [(10)] that is connected, via a flexural spring system [(30, 31; 32, 33)], with the anchoring device [(21; 21'; 25')] in such a way that the area of connection with the anchoring device [(21; 21'; 25')] is located essentially in the center of the ring, so that the annular flywheel [(10)] is able to be displaced, elastically from its rest position, about an axis of rotation [(z)] situated perpendicular to the substrate surface, and about at least one axis of rotation [(y)] situated parallel to the substrate surface. The anchoring device [(21; 21'; 25')] has two bases [(21; 21')] that are situated opposite one another and are connected fixedly with the substrate [(100)], connected with one another via a bridge [(25')]. A V-shaped flexural spring [(30, 31; 32, 33)] of the flexural spring system [(30, 31; 32, 33)] is attached to each of the opposite sides of the bridge [(25')] in such a way that the apex is situated on the bridge [(25')] and the limbs are spread towards the flywheel [(10)] with an opening angle.

[(Figure 1)]

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# MICROMECHANICAL YAW RATE SENSOR

## Background Information

The present invention relates to a micromechanical yaw rate sensor, having a substrate that has an anchoring device provided on the substrate, and having an annular flywheel that is connected, via a flexural spring device, with the anchoring device in such a way that the area of connection with the anchoring device is located essentially in the center of the ring, so that the annular flywheel is able to be displaced, elastically from its rest position, about an axis of rotation situated perpendicular to the substrate surface, and about at least one axis of rotation situated parallel to the substrate surface.

Yaw rate sensors are known from M. Lutz, W. Golderer, J. Gerstenmeier, J. Marek, B. Maihöfer, and D. Schubert, "A Precision Yaw Rate Sensor in Silicon Micromachining"; SAE Technical Paper, 980267, and from K. Funk, A. Schilp, M. Offenberg, B. Elsner, and F. Lärmer, "Surface-micromachining of Resonant Silicon Structures"; The 8th International Conference on Solid-State Sensors and Actuators, Eurosensors IX, Stockholm, Sweden, 25-29 June 1995, pp. 50-52.

Figure 2 shows a schematic top view of a known micromechanical yaw rate sensor.

In Figure 2, the character 100 designates a substrate in the form of a silicon wafer. 10 designates an annular flywheel; 15, 15' designate flexural sensors; 25 designates a bridge; 18, 18' designate a respectively curved flexural spring, and 20, 20' designate a base. The latter parts are manufactured from polysilicon over a silicon oxide layer, the silicon oxide layer being removed later in the process through undermining, in order to form the parts so that they can be displaced in relation to substrate 100. Only the two bases 20, 20' are anchored on the substrate over the silicon oxide layer, and form fixed points of the sensor structure.

The functioning of the yaw rate sensor constructed in this manner is based on the principle of the law of conservation of angular momentum of a rotating system.

In general, the following holds:

$$\overline{M} = \overline{J \cdot \tfrac{d\omega}{dt}} \, x \, \overline{\Omega} \,,$$

where M is the moment of deviation, J is the mass moment of inertia, dω/dt is the angular velocity of the rotary oscillation, and Ω is the sought yaw rate.

If, in the known yaw rate sensor according to Figure 2, annular flywheel 10, which is rotating about the z axis, is rotated about its y axis, this flywheel performs a rotation about the x axis. Given a constant angular velocity about the z axis, this rotation about the x axis, which is caused by the above moment of deviation M, is directly proportional to the sought yaw rate Ω.

In general, the problematic on which the present invention is based is that the first three natural frequencies corresponding to the x, y, and z axes, indicated in the Figure, do not have a position that is optimal or that can be optimized easily in the context of a process.

In particular, a modification of the sensor mass for the adjustment of the first three natural frequencies is undesirable, because this has effects that are disturbing with respect to measurement technology.

Advantages of the Invention

The underlying idea of the present invention is that the anchoring device has two bases, situated opposite one another, that are connected fixedly with the substrate and are connected with one another via a bridge. A V-shaped flexural spring of the flexural spring device is attached to each of the opposed sides of the bridge in such a way that the apex is located on the bridge, and the limbs are spread out towards the flywheel with an opening angle.

The first natural frequency about the z axis can be set by determining the spring width and spring length of the V-shaped flexural springs, corresponding to the operating frequency in the forced mode of the sensor. By modifying the opening angle between the respective spring limbs, the detection resonance frequency of the sensor, i.e., the rotation out of the plane of the substrate about the x or y axis, can be set. The ratio of the natural frequencies to one another determines, to a considerable extent, the sensor properties, such as for example sensitivity, immunity to interference, and temperature stability.

The inventive micromechanical yaw rate sensor having the features of claim 1 therefore has, in relation to the known solutions, the particular advantage that via the opening angle, or the width and length, of the V-shaped flexural springs, the natural frequencies can be adjusted in a simple and precise manner, independently of one another.

Advantageous developments and improvements of the micromechanical yaw rate sensor indicated in claim 1 can be found in the subclaims.

According to a preferred development, the opening angle is equal for both V-shaped flexural springs of the flexural spring device. Thus, only one angle need be optimized for the natural frequencies.

According to a further preferred development, the V-shaped flexural springs of the flexural spring device are attached to the bridge in such a way that they form an X shape. This creates a symmetrical shape of the flexural springs.

According to a further preferred development, the opening angle is selected such that the natural frequency about the axis of rotation situated perpendicular to the surface of the substrate is smaller than each natural frequency about an axis of rotation situated parallel to the surface of the substrate. In this way, an extraordinarily positive acquisition characteristic can be achieved.

According to a further preferred development, the bases at the opposed sides are fashioned with a wedge shape. Here, the bridge connects the two wedge tips with one another. In this way, the sensor obtains a good capacity for displacement about the z axis.

According to a further preferred development, the bridge is suspended freely over the substrate.

According to a further preferred development, it can be manufactured using silicon surface micromechanical technology. The use of surface micromechanical technology to manufacture the inventive micromechanical yaw rate sensor, specifically the series production process having a thick epipoly layer, typically 10 μm thick, enables the formation of a rigid sensor structure, which enables a low cross-sensitivity to be achieved.

Drawings

An exemplary embodiment of the invention is shown in the drawings, and is explained in more detail in the following specification.

Figure 1 shows a schematic top view of a specific embodiment of the inventive micromechanical yaw rate sensor, and

Figure 2 shows a schematic top view of a known micromechanical yaw rate sensor.

Description of the Exemplary Embodiments

In the Figures, identical reference characters designate identical or functionally identical components.

Figure 1 shows a schematic top view of a specific embodiment of the inventive micromechanical yaw rate sensor.

In Figure 1, in addition to the reference characters already introduced, 30-33 designate flexural spring limbs of two V-shaped flexural springs, 25' designates a bridge, 21, 21' designate bases, and 150 designates an electrical supply line.

In the micromechanical yaw rate sensor according to this specific embodiment, as in the known example according to Figure 2, annular flywheel 10 is connected with anchoring

device 21, 21', 25 via a flexural spring device made up of the two V-shaped flexural springs, in such a way that anchoring device 20 is located essentially in the center of the ring, so that annular flywheel 10 so that the annular flywheel is able to be displaced, elastically from its rest position, about the z axis, situated perpendicular to the surface of the substrate, and about the x and y axes, situated parallel to the surface of the substrate.

However, anchoring device 21, 21', 25' has two bases 21, 21' situated opposite one another and connected fixedly with substrate 100, and fashioned with a wedge shape at the opposed sides, bridge 25' connecting the two wedge tips with one another. Bridge 25' is suspended freely over substrate 100 from bases 21, 21'.

At each of the opposite sides of bridge 25', one of the V-shaped flexural springs, made up of limbs 30, 31 or 32, 33, is attached in such a way that the respective apex is located on bridge 25', and limbs 30, 31 or 32, 33 are spread out towards flywheel 10 with an opening angle.

The opening angle is equal for the two V-shaped flexural springs of the flexural spring device, and the V-shaped flexural springs of the flexural spring device are attached to bridge 25' in such a way that they form a symmetrical X shape.

The first natural frequency about the z axis can be set by determining the spring width and spring length of limbs 30, 31, 32, 33 of the V-shaped flexural springs. By determining the opening angle between the respective spring limbs, the natural frequency can be set for the rotation out of the substrate plane about the x or y axis. The ratio of the natural frequencies to one another is determined such that the sensor properties, such as for example sensitivity, immunity to interference, and temperature stability, assume an optimized value specific to the application.

Here the opening angle is for example selected such that the natural frequency about the z axis, situated perpendicular to the substrate surface, is smaller than each natural frequency about an axis of rotation situated parallel to the substrate surface, i.e., the x or y axis.

The micromechanical yaw rate sensor according to this specific embodiment is preferably manufactured using silicon surface micromechanical technology.

Although the present invention has been specified above on the basis of preferred exemplary embodiments, it is not limited to these, but rather can be modified in a multiplicity of ways.

In particular, the geometry of the flywheel, as well as of the flexural spring systems, is not limited to the indicated examples. However, larger deviations from the symmetrical arrangement about the anchoring should be avoided whenever there is a danger that linear portions of the external acceleration will falsify the measurement result.

The described packaging and manufacturing process is likewise to be understood only as an example, and other methods, such as for example galvanic methods, can likewise be used to manufacture the yaw rate sensor.

What is claimed is:

1. A micromechanical yaw rate sensor, comprising:

a substrate (100) having an anchoring device (21; 21') provided on the substrate (100); and having an annular flywheel (10) that is connected via a flexural spring device (30, 31; 32, 33) with the anchoring device (21; 21'; 25') in such a way that the area of connection with the anchoring device (21; 21'; 25') is located essentially in the center of the ring, so that the annular flywheel (10) is able to be displaced, elastically from its rest position, about an axis of rotation situated perpendicular to the substrate surface, and about at least one axis of rotation situated parallel to the substrate surface;

wherein the anchoring device (21; 21'; 25') has two opposite bases (21; 21') that are connected fixedly with the substrate (100), which are connected with one another via a bridge (25'), and a V-shaped flexural spring (30, 31; 32, 33) of the flexural spring device (30, 31; 32, 33) is attached to each of the opposite sides of the bridge (25') in such a way that the apex is situated on the bridge (25') and the limbs are spread towards the flywheel (10) with an opening angle.

2. The micromechanical yaw rate sensor according to Claim 1,

wherein the opening angle is equal for the two V-shaped flexural springs (30, 31; 32, 33) of the flexural spring device (30, 31; 32, 33).

3. The micromechanical yaw rate sensor according to Claim 2,

wherein the V-shaped flexural springs (30, 31; 32, 33) of the flexural spring device (30, 31; 32, 33) are attached to the bridge in such a way that they form an X shape.

4. The micromechanical yaw rate sensor according to Claim 3,

wherein the opening angle is selected such that the natural frequency about the axis of rotation (z) situated perpendicular to the substrate surface is smaller than each natural frequency about an axis of rotation (x, y) situated parallel to the substrate surface.

5. The micromechanical yaw rate sensor according to one of the preceding claims,

wherein the bases (20; 21') at the opposite sides are fashioned in the shape of a wedge, and the bridge (25') connects the two wedge tips with one another.

6. The micromechanical yaw rate sensor according to one of the preceding claims, wherein the bridge (25') is suspended freely over the substrate (100) from the bases (21; 21').

7. The micromechanical yaw rate sensor according to one of the preceding claims, wherein it can be manufactured using silicon surface micromechanical technology or using another micromechanical technology.

Abstract

The invention provides a micromechanical yaw rate sensor having: a substrate (100) having an anchoring device (21; 21') provided on the substrate; and an annular flywheel (10) that is connected, via a flexural spring system (30, 31; 32, 33), with the anchoring device (21; 21'; 25') in such a way that the area of connection with the anchoring device (21; 21'; 25') is located essentially in the center of the ring, so that the annular flywheel (10) is able to be displaced, elastically from its rest position, about an axis of rotation (z) situated perpendicular to the substrate surface, and about at least one axis of rotation (y) situated parallel to the substrate surface. The anchoring device (21; 21'; 25') has two bases (21; 21') that are situated opposite one another and are connected fixedly with the substrate (100), connected with one another via a bridge (25'). A V-shaped flexural spring (30, 31; 32, 33) of the flexural spring system (30, 31; 32, 33) is attached to each of the opposite sides of the bridge (25') in such a way that the apex is situated on the bridge (25') and the limbs are spread towards the flywheel (10) with an opening angle.

(Figure 1)

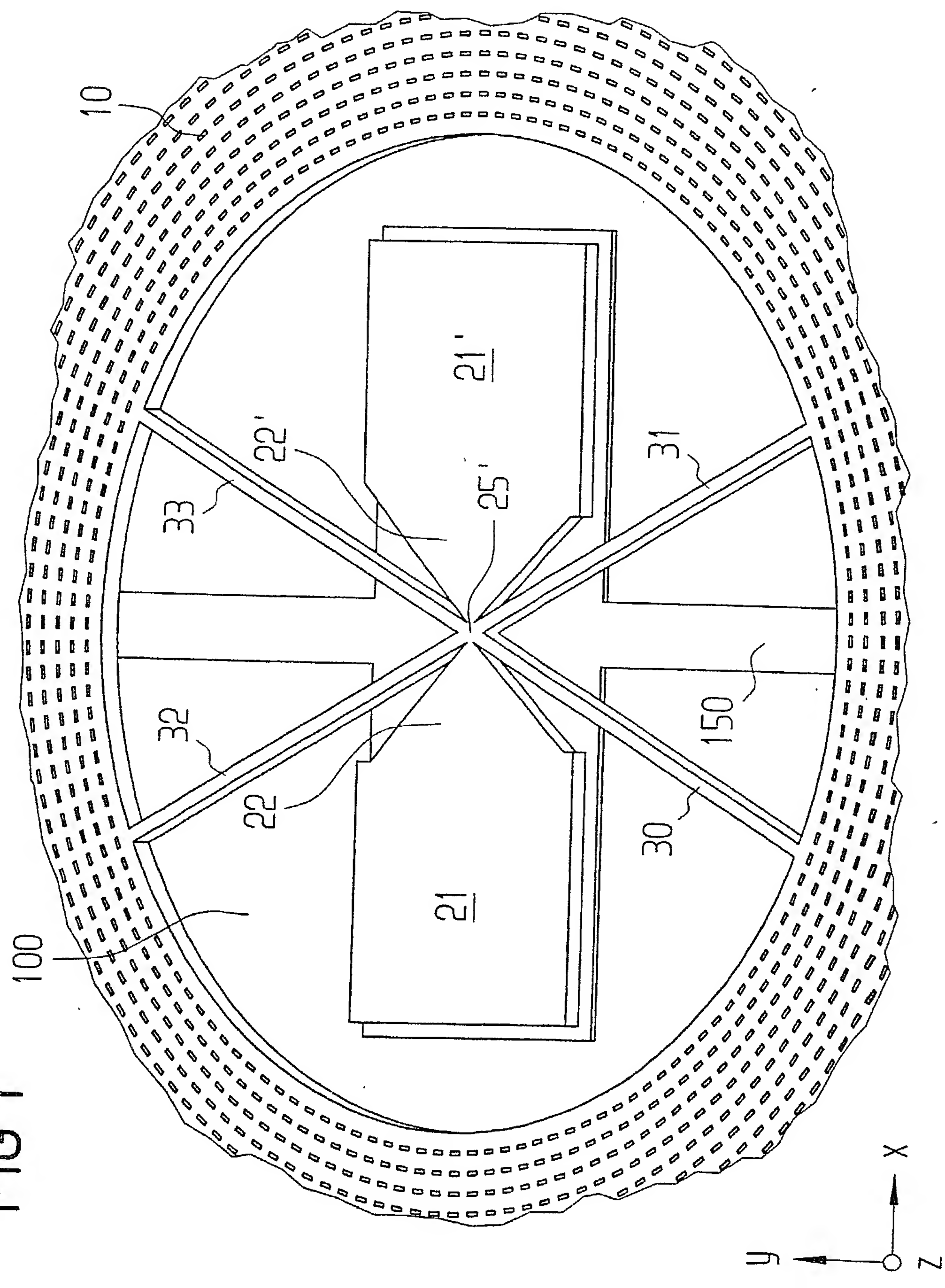


FIG 1

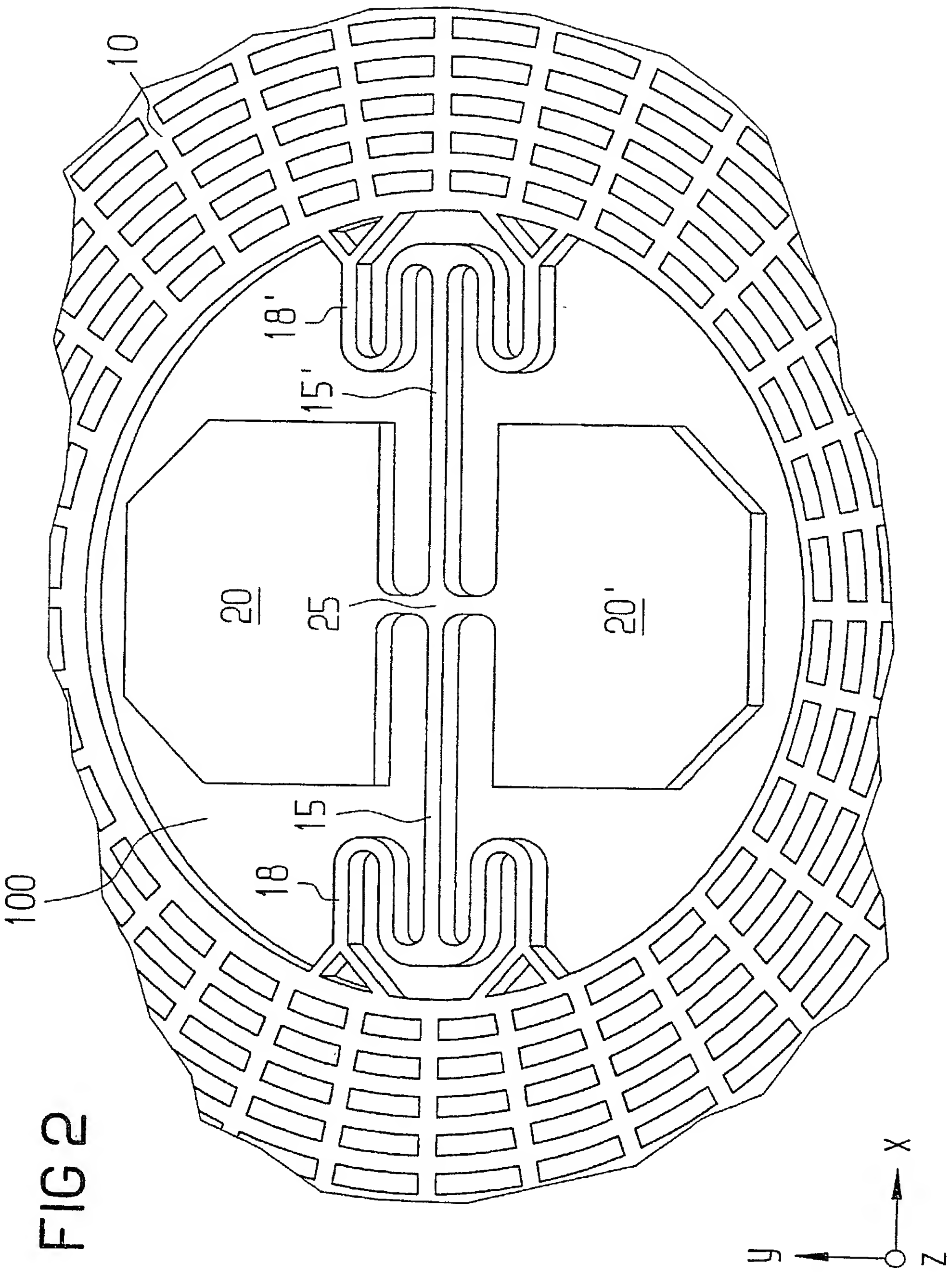


FIG 2

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# DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **MICROMECHANICAL YAW RATE SENSOR**, the specification of which was filed as International Application No. PCT/DE00/02931 on August 26, 2000.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

EL234418091

~~EL594613405~~

## PRIOR FOREIGN APPLICATION(S)

| Number | Country Filed | Day/Month/Year Under 35 USC 119 | Priority Claimed |
|---|---|---|---|
| 199 45 859.6 | Fed. Rep. of Germany | 24 September 1999 | Yes |

And I hereby appoint Richard L. Mayer (Reg. No. 22,490) and Gerard A. Messina (Reg. No. 35,952) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

1-00

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